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ONTARIO AGRICULTURAL COLLEGE.

CHARACTER AND TREATMENT OF SWAMP
OR MUCK SOILS.

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Of late years considerable attention has been given to the study of swamp or muck soils, including their chemical composition, manurial treatment, reclamation and permanent improvement. In the Province of Ontario alone we have thousands of acres of such soils, many of them valueless and abandoned, others yet unreclaimed, large areas under cultivation but yielding poor crops, whilst others again are some of our richest and most productive soils. The economic importance of this question will, therefore, be clearly recognized when we remember that according to the Report of the Ontario Agricultural Commission appointed in 1881 "to enquire into the Agricultural resources of the Province of Ontario, the progress and condition of agriculture therein, and matters connected therewith," almost every township is reported to have some such land, the estimated acreage varying from a few hundred to forty thousand or more. In the aggregate, there must have been hundreds of thousands of these swamps.

Outside of Canada the great stretches of moorland in Northern Germany, the fens of Eastern England, the heaths of Scotland, the peat bogs of Ireland, the everglades of Florida, and a vast extent of territory in other States of the Union, are familiar examples.

Undoubtedly, in some instances, the owners of these lands have gone to considerable expense in draining these areas, but in many cases the results have been far from satisfactory. Indeed, in some cases the cultivation of ordinary farm crops has been abandoned, and the land allowed to remain in pasture. There is not the slightest doubt that these soils, if properly understood and cultivated, would form a valuable asset of wealth to the Province, and the object of this Bulletin is to deal with the nature of these soils and their treatment, and the subject is taken up as follows:—

First, origin, formation and composition; secondly, the application of various fertilizers, commercial and otherwise; thirdly, reclamation and

subsequent treatment by means of drainage and other mechanical means resulting in their permanent improvement and conversion into tillable soil and, lastly, some of the causes of their unproductiveness and suggested remedies for the same.

While it will not be possible to locate and investigate, and more particularly to analyze fully, all the different areas of peaty or swampy soils throughout Ontario, until a detailed soil survey be extended throughout the Province, and soil maps be drawn out, nevertheless, we have already obtained much information of a very valuable and practical character from over nine hundred of our farmers in this Province. A circular letter was sent out to a large number, asking for particulars as to what acreage of swamp land was cultivated on their farm, the nature of the original tree growth, the length of time of cultivation, the nature of the subsoil, whether drained, and if so, how, and as to whether the yields had been satisfactory or not, and what crops appeared to do best. Replies came in rapidly, and a most valuable mass of material from some of our most successful and intelligent farmers was thus gathered together, most of the information being of a very practical character.

Reference is made to these letters throughout this Bulletin, and extracts are quoted from them, and the whole has been published because we know that this information can be used by many of our farmers with advantage and profit.

DISTRIBUTION.

Some idea of the distribution of these soils throughout the Province can be gained from noting the counties from which we have received samples of muck soils for analysis. (See Table I.) Soil 1 came from Dundas, soils 2, 3 and 4 from Lanark, 5 from Russell, 6 from York, 7 from Kent, 8 from Hastings, 9 from Simcoe, 10 from Grey, 11 and 12 from Victoria, 13 from Carlton, 14 and 15 from Renfrew, 18, 19 and 20 from Wellington, 22 from Lambton, 23, 24 and 25 from Abitibi, 26 from Bruce, and 27 from Essex. Every one of these counties have considerable areas of swamp soil, and many other counties, the soils of which we have not examined, also contain large tracts of swamp land.

The term peat, swamp, or muck soil, is applied to a class of soils formed almost exclusively of the more or less decayed residues of vegetation, as roots, leaves, and aquatic plants, but especially mosses, particularly partially decayed sphagnum moss.

ORIGIN AND FORMATION.

Usually these swamps are formed in low-lying places where the seepage water from the surrounding land has collected, or along river banks or lake shores. The water naturally contained some plant nutrients that formed food for certain forms of plant life which could live under the prevailing conditions. The presence of water excluded

air and prevented the complete decomposition of the vegetable matter. Thus, year after year, and possibly century after century, the organic matter accumulated until it was one or many feet deep. When the surface of this accumulated organic matter rose to near the level of the surrounding land, so that the surface water drained off during the summer months, trees of various kinds capable of growth in such a soil took root and grew. Thus, cedar, tamarac, elm and ash swamps were formed. Or, according as other conditions prevailed, marshes, growing reeds and sedges of various kinds may have formed. Finally, as the land was needed for cultivation, timber and stumps have been cleared away, and the swamp soils in various stages of decomposition remain, mostly covered with a rank growth of coarse grasses and mosses, and frequently considered of little value for raising crops.

CHARACTER OF THE SOIL.

All these filled in bog or swamp areas, then, naturally contain materials rich in organic matter, and, consequently, in nitrogen. However, owing to the high acidity of the peat and bog water, poor aeration of the entire mass, and to low temperature, the action of the nitrifying germs (germs that convert organic nitrogen into soluble nitrates), is almost entirely prevented, and, as a result, very little, if any, of the large amount of nitrogen present is in a form that can be assimilated by domestic plants. This class of soils is also usually deficient in potash, although they frequently contain rather large quantities of magnesia and lime, and about the normal amount, or a little less, of phosphoric acid. On the other hand, where a certain amount of sediment from the surrounding upland mixed in with the accumulating organic matter during the filling up period, and when the temperature is more favourable, bacterial action is more active and the organic matter decays more rapidly. Such soils are naturally less acid and contain more potash than other swamp soils, and may be brought into a productive condition very much more quickly than the deposit in the deeper and colder bogs.

The peaty soil varies from almost pure brown peat, containing 80 per cent. or more of combustible matter, to black muck containing much organic matter.

In a true swamp soil such as this Bulletin treats of, the peaty matter is frequently found throughout the Province from one to several feet deep, and in various stages of decomposition. Some of the samples of soil sent to this laboratory for analysis showed that decay had proceeded far enough to give it a good physical condition, while others consisted almost wholly of partially decayed wood and plants of such a nature that when drained it dried out too much, and, because of the coarseness of its texture, could not lift water by capillarity from the abundant supply lying immediately below.

In some cases our farmers have entertained an erroneous idea with reference as to what constitutes a swamp soil. A low-lying black soil,

two to four inches deep, does contain considerable organic matter and is rich in nitrogen, but it is usually mixed with large quantities of mineral matter, and is not of the true swamp type. Sometimes, however, when the swamp land has been under cultivation for a long time, or when the greater part of the organic matter has been burned off, the vegetable matter may not be any deeper than that mentioned above. The value of such land will depend largely upon the nature of the subsoil and the care exercised in the handling of it.

The productiveness of swamp soils appears to be more or less dependent on the nature of the tree growth. Correspondents throughout Ontario have generally agreed that where the original growth was tamarac or black spruce the soil was rather unproductive. Indeed, many farmers stated emphatically that reclaimed tamarac swamps made very poor farm lands.

The nature of the subsoil also influences productiveness. In general, when the swamp material lies over clay, it will be rich in potash, and the yields are frequently excellent. A sandy subsoil invariably yields poor results. There also seems to be a general agreement among correspondents that the deeper the black layer of organic matter the poorer the crop returns. In many cases where there is two or three feet of muck, sufficiently drained, and decomposed enough to allow of it holding moisture, the crops have been excellent for a few years. Gradually, however, the crops have become less and less satisfactory, until farmers seem to have lost hope of ever obtaining remunerative returns.

The acidity of these soils is a point worthy of note. When decomposition of soils rich in vegetable matter takes place, large quantities of various acids are formed. These must find in the soil bases with which to combine, or else the excess of unneutralized acid present will become injurious, arresting nitrification, and checking growth. The most common base with which these acids combine is lime, and soils containing a large amount of free acid are generally lacking in that constituent. It has been conclusively shown by the analysis of many swamp soils scattered throughout Ontario that usually they do not give an acid reaction, but, on the contrary, are rich in lime, the percentage of which in most cases has been much higher than that in ordinary clay loams. Out of forty-four samples analyzed, only three were found to contain less than one per cent. of lime, and none of them were noticeably sour or acid. In this respect they show a marked difference to the sour or acid swamp soils of Illinois, which are mostly deficient in lime. This point of high lime content should be borne in mind, as it influences the form in which commercial fertilizers are applied, as will be shown later.

HOW TO ASCERTAIN IF SOILS ARE OF AN ACID NATURE.

It is a simple matter for the farmer himself to find whether or not a soil has acid or sour properties. Take a narrow strip of blue litmus

paper (which may be obtained at the druggist's), about two inches long. Place a few ounces of the muck soil in a glass, and make it into a sticky mass by adding a little water and stirring. Let it stand for half an hour, and then by means of a knife separate the mass, and insert in it the strip of litmus paper, and press the moist soil against it. Allow it to remain for about five minutes. Remove the paper and see if the end placed in the soil has changed from its blue colour to red. If such a change has occurred, it proves that the soil is acid, and that liming will prove beneficial. Handle the litmus paper as little as possible, and be sure that it is distinctly blue before placed in the soil, for much handling will also redden it.

This blue litmus paper test furnishes also a good means for testing for acidity in subsoils, or soils very deficient in organic matter, where the acid substance may be largely of mineral origin. A good supplementary test, which is applicable only in soils containing a good deal of humus, is made by means of adding dilute ammonia water to soils. (Ammonia, too, can be bought from druggists at slight expense.) In making this test take two glasses, place a level tablespoonful of soil in each, then add water until the glasses are about two-thirds full. Now add a tablespoonful of dilute ammonia water to one of the glasses. Stir each with a different spoon. If, after standing some hours, the liquid in the one to which the ammonia water was added has become dark brown or black, it may be concluded that acid humus was probably present, hence that liming will prove beneficial.

It might be stated here that the "acid test" outlined above with litmus paper will give reliable results in every case where an appreciable amount of acid is present. If, however, the soils be but slightly acid, the test may not be sufficiently delicate to indicate it.

CORRECTION FOR ACIDITY.

Soils which contain, naturally, enough lime in suitable form do not become sour, because the acid substances which are formed during the decomposition of plants unite with the lime, forming what is known as "mild humus," and when such is the case ammonia water fails to give dark or black extracts, such as are obtained with soils containing "sour humus."

Owing to the tendency of muck soils to acidity, it is important that there should be a small amount of lime (as carbonate) present in the soil. The chemical corrective for an acid is an alkali. Quick lime and slaked lime are alkaline substances, and their application is probably the cheapest, most effective, and most permanent means of correcting acidity in soils. Other alkaline substances, such as wood ashes, basic slag, etc., are also effective means of correcting acidity.

Since the simple tests for acidity in soils have been pointed out, there is no reason why anybody should cultivate acid soil without being aware of it, and without correcting the condition by liming. Let it be

further understood that the tendency to acidity which exists in the case of all soils which lack lime is much greater when certain artificial fertilizers are used than when only stable manure is employed. Bone-meal and Basic slag, gradually correct soil acidity, while the immediate effect of acid phosphate may be to make it more acid. Kainite and Muriate of potash are likely to increase the acidity of soils more rapidly than Sulphate of potash.

With this brief review of a few of the more important facts relating to acidity, it is interesting to note that practically all of the muck soils examined at this station contain fair amounts of lime. This does not, however, mean that all of the muck soils in this Province contain sufficient lime to counteract the tendency to sourness. Muck soils have come under our observation which exhibit a highly acid condition. In such cases liming should be resorted to. But, for reasons which will be explained later, the practice of applying lime to all muck soils is not in keeping with the requirements of the case.

UNPRODUCTIVENESS DUE TO ACIDITY.

It has been observed that marked and lasting improvements of soil conditions resulted from the application to acid soils of such materials only as are capable of reducing or overcoming soil acidity. While there can be no question but that these substances improve the physical properties of the soil in certain cases, and, in some instances, doubtless proved of some value as direct plant foods, the evidence that their beneficial action was chiefly by virtue of neutralizing acidity appears to be indisputable.

THE INORGANIC SOIL CONSTITUENTS.

Of these only Potash, Phosphoric Acid, and Lime, need be discussed here, together with a short note on Nitrogen.

POTASH. Potash is usually found most abundantly in clays, where it results from the decomposition of feldspathic rock. In swamp soils it is liberated by the decomposition of the woody matter and peat. To the farmer, this substance is most important, since it is one of the three usually most deficient in swamp soils, and which must frequently be applied in the form of fertilizer before the soil can become productive. Potash is needed particularly by the young growing plant, as it helps to build up the tissue and to form a stiff, strong straw, less apt to lodge. Potash is taken from the soil by crops in the earlier stages of plant growth. In the case of wheat, three-quarters of the potash is taken up before the plant "heads out." Corn requires its potash chiefly during the first six weeks of its growth. Flax also makes a heavy demand on potash at an early period of its growth. Potash salts concentrate principally in the stem and straw of plants.

PHOSPHORIC ACID. All plants need an abundant supply of available phosphates at very early stages of growth. Wheat, for instance, requires about 80 per cent. of its phosphates in the first half of the growing period. Clover assimilates practically all it needs by the time it reaches full bloom. Phosphates are absolutely essential to the production of grain, and usually concentrate in the seeds of all plants. Light weight grain is often the direct result of lack of available phosphoric acid, and this would seem to be the cause of so much light grained oats, barley and wheat, being raised on our swamp soils. This whole question will be treated more fully, however, under the heading "Application of Direct Fertilizers."

LIME. Lime is also an important constituent of plant food. Directly and indirectly, lime is of great service to growing crops, and many agricultural authorities place the minimum limit in a soil for good returns at 1.0 per cent. The presence of lime favours the nitrification of humus, and also sets free inorganic elements of plant food.

NITROGEN. Nitrogen is absolutely essential to all vigorous, healthy growth. It is used by the plant principally in building up the proteids of all grains. It is also a constituent of the green colouring matter of all plants, and the yellow colour growth of so many of our cereals grown on swamp soils, is, in some cases, due to the lack of available nitrogen in these soils, in spite of the large amounts of total nitrogen which they may contain. Moreover, as in the case of potash and phosphoric acid, nitrogen is also needed by the plant in its earliest growth, soon after germination in fact, and if it be absent at this time, a subsequent later application made on the growing crop will not help it to any very great extent. In this connection it must also be remembered that climatic conditions and season influence the application of nitrogenous fertilizers to a great extent. In late, wet seasons, the production of nitrates is retarded owing to the undrained, cold nature of the soil, and an application of a quick acting fertilizer, as sodium nitrate, generally gives marked results, giving the crop the required start.

VALUE OF A CHEMICAL SOIL ANALYSIS.

Such questions as the following are, we believe, capable of being answered in this Bulletin, and we trust may prove of some value in connection with a study of swamp soils: Is this soil able to produce good crops without the aid of artificial manuring? If so, how long can constant cultivation be practised without a diminution in the yield of the crop? In what elements does it seem to be well supplied, and more particularly, in what does it seem to be deficient, and therefore, what fertilizer will yield the best results? And, lastly, what crops are best suited to these soils, and how are they apt to behave?—the latter, of course, depending largely on the nature of the season.

A considerable number of swamp soils from different places in the Province have been analyzed by this station, and they are found to be for the most part very rich in Nitrogen, a fair supply of Phosphoric

acid, rather low in some cases, but mostly deficient in Potash as compared with the ordinary fertile soils of our Province. It has long been known that such soils are frequently deficient in mineral elements, particularly in a soluble form, and the behaviour of crops on these soils bears that out.

TABLE NO. 1.—CHEMICAL ANALYSIS OF SWAMP OR MUCK SOILS.

	Moisture.	Organic and volatile matter.	Insoluble matter (sand, etc.)	Oxides of iron and aluminum (Fe_2O_3 & Al_2O_3).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).	Phosphoric acid (P_2O_5).	Nitrogen in organic matter.
	%	%	%	%	%	%	%	%	%
No. 1.....	12.68	72.10	9.45	3.75	5.25	1.06	0.13	0.15	2.64
No. 2.....	5.21	70.71	10.69	4.93	7.39	0.42	0.52	0.10	2.27
No. 3.....		60.80	23.26	5.41	6.22	0.70	0.23	0.08	2.25
No. 4.....		64.86	2.46	4.35	4.99	0.36	0.23	0.31	1.82
No. 5.....	14.28	56.41	12.03	4.55	0.49	1.49	0.42	0.02	
No. 6.....	12.05	57.39	21.64	9.51	3.68	2.11	0.07	0.20	2.65
No. 7.....	7.35	48.63	31.54	1.66	1.95	0.45	0.03	0.09	1.14
No. 8.....	2.74	72.58	8.13	3.17	3.18	1.53	0.40	0.16	2.59
No. 9.....	6.60	43.09	41.00	3.72	4.15	0.57	0.18	0.01	0.92
No. 10.....	8.25	89.10	2.58	2.61	1.42	0.08	0.05	0.12	1.92
No. 11.....	3.71	85.20	4.53	1.46	1.21	0.60	0.11	0.09	2.25
No. 12.....	20.12	39.44	31.01	4.02	2.75	0.45	0.07	0.29	1.16
No. 13.....	16.22	68.51	3.92	4.26	5.35	0.48	0.21	0.28	1.85
No. 14.....	10.90	75.55	3.40	3.80	4.11	0.63	0.13	0.05	2.42
No. 15.....	15.49	60.88	15.92	2.17	5.43	0.75	0.09	0.11	1.81
No. 16.....	9.54	90.15	2.16	1.75	0.95	0.01	0.06	0.19	1.63
No. 17.....	2.76	92.51	1.00	1.54	0.97	trace	0.01	0.25	2.80
No. 18*	11.71	53.02	21.40	0.54	5.42	0.15	0.21	0.22	1.64
No. 19*	11.29	52.77	27.22	1.40	3.68	0.09	0.33	traces	1.16
No. 20*	7.63	77.81	3.16	1.18	5.53	0.04	0.14	0.17	1.45
No. 21*	7.48	77.91	4.45	1.55	4.43	0.04	0.11	0.27	2.60
No. 22.....	6.1	49.9	28.8	10.91	2.86	0.71	0.09	0.14	2.88
No. 23.....	12.14	74.46	4.26	0.85	2.92	trace	0.12	0.30	1.41
No. 24.....	0.41	71.19	6.04	6.94	5.93	trace	0.20	0.29	
No. 25.....	14.17	74.64	3.09	0.17	2.66	trace	0.11	0.32	1.83
No. 26.....	13.01	41.63	30.74	2.86	2.88	0.65	0.33	0.29	0.47
No. 27.....	9.86	78.52	3.66	3.17	2.45	0.04	0.25	0.39	1.99

* College Farm, Wellington County.

TABLE II.—ANALYSIS OF FERTILE SOIL TYPES.

	Sandy Soil.	Sandy Loam.	Loam.	Clay Loam.	Heavy Clay.	Calcar- eous Soil.
	%	%	%	%	%	%
Moisture						
Organic and volatile matter ...	.49	8.05	5.58	5.42		6.41
Insoluble matter (sand, etc.) ...	93.14	77.59	81.42	80.76	74.40	30.04
Oxides of iron and aluminum (Fe_2O_3 & Al_2O_3)	5.80	6.75	7.28	10.00	12.02	6.55
Lime (CaO)	.21	.45	1.23	1.15	1.04	31.36
Magnesia (MgO)	.42	.31	1.02	.58	.91	2.12
Potash (K_2O)	.13	.25	.46	.68	.90	.33
Phosphoric acid (P_2O_5)	.07	.34	.36	.28	.47	.15
Undetermined,						
Per cent. of nitrogen in soil....	.16	.18	.31	.27	.29	...

It must be stated here that although a chemical soil analysis cannot be considered to state definitely whether a soil will yield productive crops or not, yet it is a clear indication of the total amount of plant food present, and if this figure be low, then clearly the soils are deficient in certain mineral constituents (principally potash and phosphoric acid), and to yield heavy crops must be supplied with additional plant food in the form of various commercial fertilizers.

Looking at the percentage of nitrogen in these soils we find that it is very high in every case. Notwithstanding this fact, crops are often observed to be of a yellow colour and of a weak, sickly growth when grown on these soils. This condition when seen in other soils, is usually put down to a lack of nitrogen, or to the *scalding* effect of water. The same can apply here. Though the stores of total nitrogen are so great, it is locked up in an inert condition, for the fact that decay and the subsequent nitrification has not gone far enough in some cases to break down the organic or humic compounds, and to set the nitrogen free in the soluble nitrate form. One of the first requisites, therefore, is cultivation and the addition of farmyard manure to hasten these beneficial actions, and to gradually unlock the vast stores of insoluble material.

We are sometimes asked, what is the minimum amount of each of the plant constituents that must be present in a soil in order to produce good crops. In attempting to interpret the results of a detailed chemical analysis, so many other factors affect and modify conclusions that it is extremely difficult to establish a minimum standard. * Hilgard, as the result of a great deal of work on the soils of the Southern and Western States, gives the following figures, which represent the amounts of the several essential ingredients, soluble in strong

* Report of the California Agricultural Experiment Station, 1888-89, pp. 163, et seq.

hydrochloric acid, that soils of various character should contain. It may be stated here, that the amounts of plant food extracted by strong hydrochloric acid is a comparative measure of the total amount of plant food present that can be assimilated by plants, and which may in time be rendered soluble by the organic acids exuded by the roots.

TABLE III.

Potash:

In sandy soils of great depth may be less than	0.1%
In sandy loams	0.3 to 0.1%
In loams	0.45 to 0.3%
In heavy clays and clay loams	0.80 to 0.45%

Lime:

In lightest sandy soils not less than	0.1%
In clay loams not less than	0.25%
In heavy clay soils not less than	0.50%
No advantage in having more than	2.00%

Phosphoric Acid:

Seriously deficient in virgin soils when less than	0.05%
Unless accompanied by a large amount of lime.	
Sandy soils with fair supply of lime	0.1%
Sandy soils with poor supply of lime	0.2%
Clayey soils not less than	0.2%

DISCUSSION OF TABLE I.

A brief study of the above table shows us at once the striking feature of these soils as compared with an average clay loam. In the case of humus soils we have a very low figure, from 1.00 to 41.00 per cent. of insoluble inorganic residue (sand, etc.), and a very high figure, 39.44 to 92.51 per cent. of organic and volatile matter. In the case of a clay, however, the reverse is true. Here we have but 6.26 per cent. of organic matter, and 75.76 per cent. of insoluble inorganic matter (sand, etc.). This difference is easily explained when we remember the formation of these two classes of soil. The clay loam has been formed by the breaking down of feldspar rock and other mineral constituents, while the humus soil is of organic origin. It would appear from the results of Table I. that soils 3, 6, 7, 9, 12, 15, 18, 19, giving a high per cent. (all over 15 per cent.) of insoluble inorganic residue (sand etc.), contain more or less an admixture of clay, sand or the other mineral constituents, whilst soils 4, 10, 11, 13, 14, 16, 17, 20, 21, particularly, with a very low figure for inorganic insoluble residue (none mentioned being over 4.53 per cent.) are largely of pure deep-muck formation. This theory is borne out by practical observations. Soil No. 18, for instance, occurs in a low portion of a field of arable clay loam on the College farm, and frequent cultivations have resulted in a mixing somewhat of humus (muck) and clay. Soil No. 21, on the contrary, is a reclaimed swamp that is a virgin soil, showing 77.91 per cent. of volatile and but 4.45 per cent. of inorganic and non-volatile (sand, etc.)

The only point worthy of note in the quantities of lime, magnesia, aluminum, and iron contained in the various soils, is *the high lime content in every soil analyzed*. This might readily be explained in soils No. 18, 19, which were underlaid by a bed of marl, and where deep cultivation had been practised, but how are we to explain the presence of over 5 per cent. of lime in soil 20, and over 4 per cent. in soil 21, where the subsoil was one of pure sand. This high lime content of the swamp soils of Ontario seems to be one of their characteristics. For of 54 samples analyzed in this laboratory all gave a high lime content. The presence of so much lime might be due to the percolation of seepage water from higher land. In a clay loam such high lime percentages are rarely met with. When we consider the importance of lime in the

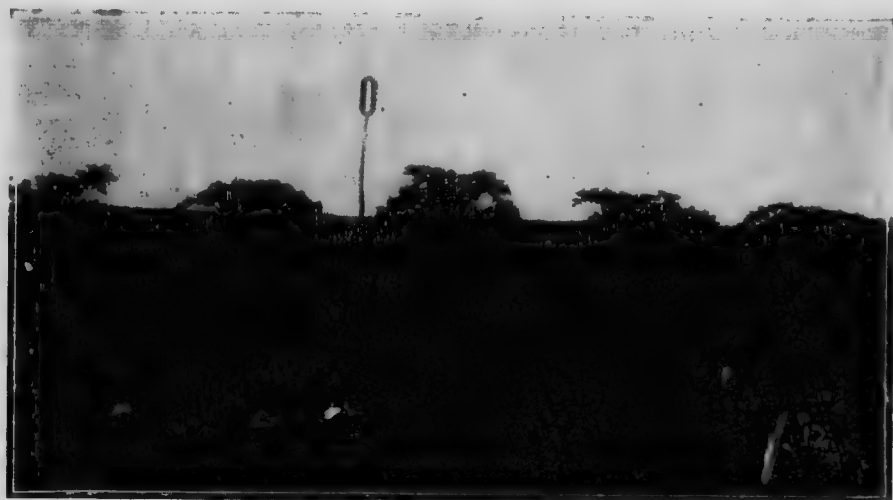


FIG. A.—Celery grown on unfertilized soil.

soil, and particularly in relation to swamp soils, the significance of this high lime content is seen. It is worthy of note that lower percentages of potash, phosphoric acid, and nitrogen are considered adequate when a high percentage of lime is present.

Coming now to the more important mineral soil constituents, namely, potash and phosphoric acid, it will be seen, that in general these soils appear to be deficient in total potash, and in very many cases in total phosphoric acid, though the latter seems to be present in greater amounts than the former. Some few soils in which the sh content is well up to the average, or even above it, may be explained by the fact that the swamp soil may be but shallow in depth and overlies a rich clay subsoil containing large amounts of potash—which, by deep and frequent cultivation has become mixed with the top soil. Mucks overlying sands are invariably deficient in potash.

BEHAVIOUR OF CROPS ON SWAMP SOILS.

It has been the general experience of our farmers in Ontario that all crops grown on swamp soils show a tendency to run to leaf and straw, and to produce a light yield of grain more or less poorly filled. The reason is evident. These soils contain a very large amount of nitrogen in the organic matter, and a relatively small amount of mineral food. Oats and rye have, however, done well, many correspondents remark, but wheat usually is a light crop. Most are agreed that it is an excellent soil for root crops of all kinds and most vegetables. Great crops of carrots and potatoes have been grown. Onions and celery seem well suited. Sugar beets have done well in many cases. As we would



FIG. B.—Celery grown on fertilized soil. KPN5. (Potash, phosphoric acid, nitrogen. Plot 5.)

naturally expect, very large yields of hay have been grown, and pastures can hardly be equalled. Red Top thrives, as it loves damp land. Corn gives large yields, and in the United States is probably grown more extensively than any other crop on muck soils. One correspondent remarks that buckwheat seeded down to clover, timothy, and meadow fescue, for a few years resulted in good yields of oats and barley later on. Another says, "it is specially adapted for hay and grass, timothy and alsike clover, yielding immense crops." Flax is grown quite extensively on these soils also, and one correspondent in Essex County remarks "that tobacco does very well." Peas in most sections seem to do very well. A farmer in Huron County remarks that on a swamp soil about 3 1-2 feet in depth and in which the subsoil was only mixed with the black top soil at the edges

of the swamp, he grew first a crop of flax three tons to the acre and then seeded to timothy, producing two enormous crops. Rye and buckwheat both seem to do well. Millet, oats, and hay are recommended by one correspondent as the most satisfactory rotation he has



FIG. 1.—Barley on muck soil, fertilized with potash.

tried. Summing up the whole question of behaviour of crops on swamp soils, it would seem from letters received that generally these soils are too wet in spring and dry out too much in summer, the same applying to wet and dry seasons. Also, a large number of the soils seem to improve with length of cultivation, others seem to deteriorate. These questions this bulletin will endeavour to throw some light upon.

It is a matter of common experience that when these soils are reclaimed by draining and ploughing the first few crops are good. Succeeding crops are not so large, and in some cases our correspondents state it becomes difficult to grow any crop upon the soil.

These soils are also sometimes very unequal in productiveness, some areas bearing good yields, while others produce little or nothing. When corn is grown upon these lands, often there will be one or two unusually large hills surrounded on all sides by plants which are very small and yellow. In the places where crops fail to develop normally it is common to find on pulling up the plants that they have a very imperfect root system, the tips of new roots appearing brown and soft much as if they had been corroded. Farmers frequently ascribe this appearance to wire worms, and they do sometimes work in these soils, but wire worms are not responsible for the deficient root system in most cases. The unproductive soil itself consists of partially decayed organic matter which does not contain sufficient mineral matter ($K_2O + P_2O_5$) to sustain root development. In some cases, however, the lands are unproductive because of bad drainage and failure to reduce the water level to the proper point. In general, we believe that for corn culture, as well as for the growth of other crops, the permanent water level must be greatly reduced.

COMPARISON OF HUMUS SOILS WITH AVERAGE TYPES OF FERTILE SOILS.

A careful study of the figures presented in Table II. shows a wide variation between the total amounts of plant food present in the more important types of soils. This, studied together with the table III. on the minimum amount of each constituent required for profitable plant growth, affords much information of value and interest. We note the high percentage of potash (K_2O) in loam, clay loam, and heavy clay, being, respectively, .46, .68, .90 per cent., and the low per cent. in a sandy soil and sandy loam, being .13 and .25 per cent., respectively. Now look at the percentage of potash in swamp soils in Table I. The figures vary from .01 to .52 per cent. In most cases the amount lies between that found in a sandy soil and a sandy loam. Take next the figures for phosphoric acid (P_2O_5). Here we have in a loam, clay loam, and heavy clay .36, .28, and .47 per cent., respectively, and in a sandy soil and sandy loam .07 and .34, respectively. In the case of the swamp soils the figures for phosphoric acid (P_2O_5) vary from traces and .01 per cent. to .39 per cent. It will, therefore, be seen that in the case of the samples of swamp soils examined by this station, the per cent. of both potash and phosphoric acid is rather low, in many cases more or less deficient, and in some few examples is present in fairly large quantities. It cannot be assumed from these figures, however, that all our swamp areas throughout Ontario are deficient, because thousands of these have never come

under our examination, but merely, that most swamp soils that have come under our notice seem to be poorly supplied with both these constituents.

One important point, however, must not be overlooked. The finer the texture of a soil the more soluble matter it will contain. In other words, we must know the physical condition of a soil before stating certain figures as representing the minimum amount of fertilizing ingredients necessary. This must be remembered when studying the figures given in Table No. III. The reason that a fine textured soil, to be fertile, must contain more soluble plant food than a coarse textured one is probably due to the well known fact that the physical power of soils to remove dissolved material from its solutions is proportional to the surface; that is, the finer the texture of the soil the greater is its absorptive capacity. Much, therefore, depends upon how far decomposition has proceeded, and as to whether most of the coarse, woody material has been reduced to a fine condition before it can be definitely stated what amount of the essential elements, particularly potash and phosphoric acid, must be present to render these soils fertile.

One must constantly bear in mind the fact that this work, its indications and conclusions, are general in character. One cannot apply it to all cases, but the farmer must use his own judgment and apply the facts to suit his own local conditions. Above all, he must give importance to his own practical experience, and that of others.

FERTILIZERS.

For our purpose fertilizers may be divided into three classes. Indirect fertilizers, bacterial fertilizers, and direct fertilizers. Before treating of each of these let us briefly consider the application of fertilizers as a whole. We must take into consideration the character and composition of the subsoil, as this is of great importance in determining whether or not fertilizers shall be applied. If the subsoil is clay it may gradually have become very rich in plant food through seepage water which has drained down into it for centuries; if sandy, most of the fertilizing materials may be lost, as the sand has not the same power of holding and fixing fertilizing materials.

If the soil has one to three feet of very peaty material and this is underlaid with a very deep sand subsoil, or with sand resting on rock; or if the peaty soil itself is very deep, three or four feet or more, then the land will almost certainly be deficient in potash, and the chief part of the potash required to produce crops must always be applied in the form of commercial potash salts, wood ashes, or farm manure, because of the simple fact that it cannot be furnished by either the soil or subsoil in sufficient quantities to produce continuous large crops. As a rule this class of soils will not need large applications of phosphoric acid, though a small quantity applied at commencement of growth usually yields good results.

Those peaty soils from six inches to three feet deep, resting upon a clay subsoil, are, as a rule, almost invariably rich in potash, which seldom needs to be applied in such cases.

INDIRECT FERTILIZERS.

Among indirect fertilizers may be classed lime and cut straw. Lime is not a direct fertilizer in that it seldom adds any plant food to the soil that is needed, many swamp soils being already well supplied with lime. In fact, over 2 per cent. of lime is not considered to have any beneficial action, and many of our swamp soils run from 2 to 5 per cent. The only case in which lime need be applied to swamp soils is when the farmer has himself carried out the acid test which has already been described. If the soil is acid, liming is the first requisite. On some of our swamp soils the application of lime has had more or less of an injurious result—decreasing the yield. It seems to refuse to mix with the muck soil, and for as long as four years after the application the white particles of lime can still be seen on the surface. Often, injury results from the application of lime in a caustic state. When applied in this form, particular care must be exercised to avoid excessive applications, even on soils where crops requiring a relatively large amount of lime are to be grown. Air-slaked lime has been found, in some cases, to give better results than lime which has been slaked by water. In any event, it is better to make lime applications some time in advance of seeding. Autumn applications are generally to be preferred. On soils needing lime, about every four or five years would be the proper interval for applying this material. Lime should, immediately after being applied, be harrowed into the soil, otherwise it will likely cake, and this would detract from its good effects. About 1,400 pounds to one ton of quick lime per acre is sufficient. Lime also can be applied by drawing it to the field and putting it in half bushel to bushel piles about two rods apart. If now covered with moist earth and a little water added, if necessary, and allowed to stand, it will quickly slake, and can then be spread on the surface with a shovel.

APPLICATION OF CUT STRAW.

Cut straw alone has not been applied as a fertilizer to any extent in Ontario. This does not refer to the common practice of applying farm-yard manure, which will be treated of later. Cut straw, however, has been successfully applied with good results in Indiana. A layer of rather short wheat straw about three inches thick was ploughed under, and corn grown. The increase in the yield of sound corn was 20.8 bush. per acre, and of fodder corn .91 tons per acre.

J. I. King, of Wisconsin, has also observed that the application of "coarse litter, like straw, ploughed in, is often very helpful." The

beneficial action of the straw is not clearly understood, but it is believed to improve the physical texture of the soil and to admit of a better circulation of air.

BACTERIAL FERTILIZERS.

Under this heading may be placed garden loam. An application of garden loam whenever applied to swamp soils at this station, has given very marked results. Only a sprinkling over the surface is required. The purpose of adding the loam is to supply the swamp soil with certain bacterial germs known as "nitrifying organisms." These are often absent in swamp soil, but very abundant in a garden loam or good field clay loam. They help to decompose the organic matter in the soil and



FIG. 2.—The muck soil in pot 12 was inoculated with garden loam. Pot 1 untreated. Crop, oats.

to break up the insoluble compounds of nitrogen, converting them into such a form that they can be used by plants. The potash and phosphoric acid is at the same time rendered more available. Soils inoculated with garden loam produce crops that stand up better, usually have a stronger straw, and are more vigorous. The accompanying photograph shows this clearly.

Pot No. 1 is untreated. Pot No. 2 had an application of loam. The crop grown was oats. It would be an easy matter for the farmer to apply one load of garden loam per acre, spreading the same over the surface, and we believe the results obtained will warrant the expenditure of the labour in nearly all cases. The application may not, however, have any effect, or be unnoticeable on muck soils that have been cultivated for a number of years, or that have had an intermixture of subsoil with surface soil. In this case, these soils have already probably been inoculated,

and therefore are capable of yielding good crops. But in the case of a reclaimed swamp growing its first crop the effect of the loam is very noticeable.

DIRECT FERTILIZERS.

In this class may be placed farmyard manure—a general fertilizer; dried blood, tankage and nitrate of soda as nitrogenous fertilizers; Kainite, Potassium sulphate, Muriate of potash, and wood ashes, as Potassic fertilizers; and Thomas phosphate or Basic slag, ground rock phosphate (floats), Superphosphate and Bone Meal, form the chief source of supply of phosphoric acid.



FIG. 3.—Muck soil in pot 13 was treated with farmyard manure. Pot B untreated. Crop oats.

APPLICATION OF FARMYARD MANURE.

Farmyard manure has been found in nearly all cases to greatly improve even the best of these lands, enabling them to give large yields. Liquid farmyard manure, however, has not been found to have an appreciable influence on the yield. This would lead us to suppose that it is the coarse litter and the straw present in the manure that is beneficial, rather than the fertilizing ingredients themselves, for the urine itself contains the greater quantity of potash, though nearly all the Phosphoric acid and the greater part of the lime is found in the solid excrement. A good dressing of farmyard manure may materially increase the yield for four consecutive years; as a rule the effect of applying potash is seen only the first and second year. An experiment to

compare the relative value of manure and blood with that of potassium sulphate was carried on at Wisconsin, with the following results. When the data are expressed as percentage of increase due to each fertilizer, it stands as follows:

Potassium sulphate	34.4 per cent.
Dried blood	20.1 per cent.
Farmyard manure	29.2 per cent.

Thus it is seen that farmyard manure and dried blood have their part in being good fertilizing materials to apply to swamp soils. The addition in every case seems to cause the greatest luxuriance of growth and earlier maturity, but with a tendency to lodge. Fig. 3 illustrates the result of the application of farmyard manure.

The good results obtained from its addition on swamp soils have been noticed by many experimenters, but wherein its great value lies is not fully understood. The reason soils so rich in organic matter and nitrogen should respond readily to the application of these slow acting organic manures is probably due to the fact that nitrifying organisms (germs) are supplied by the manure in large quantities, exactly the same as in the case of the garden loam, and these break down the organic matter, forming nitrates and releasing carbon dioxide gas, which in contact with water dissolves large quantities of mineral constituents (potash and phosphates).

APPLICATION OF POTASH.

Potash has invariably given good results. Besides the actual percentage of potash being low, the very high percentage of nitrogen causes an unbalanced condition of the soil, and potash, and frequently phosphoric acid, have both to be added to restore equilibrium, and to introduce the materials necessary for the filling of the grain.

The results of the application of potash salts, obtained from experiments conducted both at this station and throughout the Province by means of co-operative work, are placed in tabulated form, and given later.

Let us first briefly review the work done by other stations on swamp soils, and see how far it coincides favourably with our own results.

WORK OF OTHER STATIONS.

As a result of experiments with potash at Indiana, it was found that the best yield was obtained from the use of Kainite applied at the rate of 100 pounds per acre, which gave an increased yield of 27.2 bushels of corn and 1.04 tons of fodder corn per acre. Here we have clear evidence of the good results obtained by the application of Kainite.

In regard to the application of potassic fertilizers, F. H. King,

of Wisconsin, writes: "Potassium carbonate, Potassium sulphate, Potassium nitrate, and wood ashes, have all been found to greatly improve these lands for corn. Kainite also improves the yield, but to a less extent. Potassium chloride in half the quantity of the other salts killed the corn." As a result of experiments along these lines, he states as follows:

Potassium sulphate increased the stalks 2.042 times, and the ears 4.434.

Potassium chloride increased the stalks 1.893 times, and the ears 3.661.

Potassium magnesium carbonate increased the stalks 1.842 times, and the ears 3.045.

Kainite increased the stalks 1.814 times, and the ears 2.519.

Here it will be seen that the potassium sulphate gave the best results. At Michigan, the application of wood ashes, barnyard manure, and upland soil, have given the best results.

METHOD OF APPLYING POTASH.

Potash may be applied in the fall or spring, but preferably, at least one or two weeks before the crop is sown. It should be applied broadcast or in narrow drills as a general rule. All potassic fertilizers may be applied easily and quickly by hand, scattering it from the waggon. It is good practice to apply the potash after ploughing, and then to mix it with the soil by disking, harrowing, etc., in the usual preparation of the seed bed. It should not be applied when the ground is frozen over if there is likely to be any outflow or surface drainage before the potassium salt dissolves and soaks into the soil.

PHOSPHATIC FERTILIZERS.

Some swamp soils appear to be well supplied with phosphoric acid, in others it is low, particularly the soluble phosphoric acid which is frequently present in mere traces. Generally speaking, phosphatic fertilizers are not needed as much as potassic, but, in our co-operative experimental work, some excellent results have been obtained by its application. Not only does it cause an earlier maturity, but strengthening of the straw often results and a fuller, plumper grain, with an increased yield. It has generally been advocated that phosphates should be applied to swamp soils in an insoluble form, such as ground rock phosphate, or Thomas phosphate also called Basic slag. These materials are, of course, much cheaper than the more expensive chemically prepared superphosphate. They are also much slower in their action, owing to their insoluble form and also to the more or less coarse nature of the substance. Superphosphate, on the other hand, contains a large proportion of its phosphoric acid in the water soluble condition, which can be immediately used by the plant. Its action is, therefore, very much quicker.

It has been argued that if phosphates be applied as ground rock and Basic slag, then the acids that are present in muck soils will dissolve it in time, and render it available to the plant. Also, that superphosphate is itself acid in nature and, therefore, should not be applied to soils which in themselves are apt to be sour, thus increasing the total acidity. But our analyses show that our swamp soils are not generally acid, and therefore that the non-application of superphosphate for that reason does not follow. Some interesting results in fact will be found in the tables on co-operative work, showing that in some cases superphosphate has given very marked results. This is owing no doubt, as has been stated, to the lack of soluble or available Phosphoric acid in swamp soils and, therefore, the need of a dressing of phosphatic manure in a form readily accessible to the plant in its earliest stages of growth, just when it stands most in need of plant food. It stimulates the early development of the young seedlings to a remarkable extent, and gives them a good start; indeed, it is often used merely to secure a better plant, though with little expectation of otherwise increasing the yield. It must be remembered in this connection, that the crops most benefited by phosphatic manuring are turnips and barley, wheat responding very little, and mangels hardly at all.

When ground rock phosphate is used it must be seen to that it is sufficiently fine, as many coarsely ground and inferior brands are on the market. Its value depends largely on its fineness. To soils which are acid it certainly seems the cheapest and best form in which to add phosphoric acid to the soil.

RESULTS OF FERTILIZER EXPERIMENTS ON MUCK SOILS.

Oats in 1904.	Fertilizers per acre.	Yield per acre.
	lbs.	Bush.
1. No fertilizer		23.7
2. Muriate of potash	200	39.0
3. Muriate of potash	200	
Thomas phosphate.....	400	43.1

Experiments with Lime Included.

1. No fertilizer		19.0
2. Lime.....	2,400	19.6
3. Muriate of potash.....	200	35.8
4. Muriate of potash	200	
Thomas phosphate.....	400	36.7

Oats in 1905.

1. No fertilizer		28.5
2. Muriate of potash	200	41.2
3. Muriate of potash	200	
Thomas phosphate.....	400	44.1

RESULTS OF FERTILIZER EXPERIMENTS ON MUCK SOILS.—*Continued.*

Corn in 1905.		Fertilizers per acre.	Yield per acre.
		lbs.	*lbs.
1. No fertilizer			2,652
2. Muriate of potash.....	200		3,880
3. Muriate of potash.....	200		3,732
Thomas phosphate.....	400		
Oats in 1906.			
			Bush.
1. No fertilizer			24.6
2. Muriate of potash.....	200		38.1
3. Muriate of potash.....	200		51.8
Thomas phosphate.....	400		
4. Thomas phosphate.....	600		29.0
Barley in 1906.			
1. No fertilizer			39.8
2. Muriate of potash.....	160		51.0
3. Muriate of potash.....	160		51.2
Superphosphate.....	320		
Oats in 1907.			
1. No fertilizer.....			22.6
2. Muriate of potash.....	200		30.7
Lime.....	2,400		
3. Muriate of potash.....	200		30.3
Lime.....	2,400		
Thomas phosphate.....	400		
4. Lime.....	2,400		26.2
Potatoes in 1907.			
1. No fertilizer			89.2
2. Lime.....	1,400		142.7
3. Lime.....	1,400		196.0
Sulphate of potash.....	200		
Thomas phosphate.....	400		
4. Lime.....	1,400		166.6
Sulphate of potash.....	200		
Oats in 1908.			
1. No fertilizer			4.5
2. Lime.....	2,400		30.5
3. Lime.....	2,400		37.0
Muriate of potash.....	200		
4. Lime.....	2,400		40.0
Muriate of potash.....	200		
Thomas phosphate.....	400		

* Shelled corn.

RESULTS OF FERTILIZER EXPERIMENTS ON MUCK SOILS—Continued.

Corn in 1908.		Fertilizers per acre.	Yield per acre.
		lbs.	*lbs.
1.	No fertilizer		2,840
2.	Lime.....	2,400	2,840
3.	Lime.....	2,400	4,180
	Muriate of potash.....	200	
4.	Lime.....	2,400	3,580
	Muriate of potash.....	200	
	Superphosphate.....	400	

Potatoes in 1908.			Bush.
1.	No fertilizer		120
2.	Lime.....	1,400	116.6
3.	Lime.....	1,400	145.4
	Sulphate of potash.....	200	
	Sulphate of potash.....	200	196.0
	Thomas phosphate.....	450	

* Shell d.

DISCUSSION OF CO-OPERATIVE FERTILIZER EXPERIMENTS ON MUCK SOILS AT THIS STATION.

A careful study of the above table shows some very marked results from the application of fertilizers on swamp soils at this station.

The soil on which experiments were conducted in 1904 with Oats was a deep muck soil, which had been worked for about 15 years. The subsoil was calcareous. The application of Muriate of potash and Thomas phosphate on Plot 3 at the rate of 200 pounds of the former and 400 pounds of the latter per acre, increased the yield by 19.4 bushels. Muriate of potash alone on Plot 2 gave an increase of 15.3 bushels. It is interesting to note that lime applied with the Muriate of potash, and with the Muriate of potash and Thomas phosphate combined, *lessened* the yield, though lime alone increased it .6 bushels per acre.

The experiments with Oats in 1905 were conducted on a swamp soil which contained material fairly well rotted, but which did not produce good crops. In this experiment very marked results were obtained, though not quite so evident as in 1904. Muriate of potash and Thomas phosphate increased the yield in this case 15.6 bushels per acre, while Muriate of potash alone increased it 12.7 bushels per acre.

The effect on Corn was also very marked. Here the unfertilized plot yielded 2,652 lbs. of threshed corn. A mixture of Muriate of potash and Thomas phosphate increased the yield on Plot 3 by 1,080 lbs., while the Muriate of potash alone on Plot 2 gave an increase of 728 lbs. per acre. The soil in this case was a deep muck with a sandy loam subsoil, which explains the excellent results obtained by the addition of Potash.

In 1906, 1907, 1908 and 1909 the experiments were all conducted on typical swamp soils, varying from about two feet deep to as much as fifteen feet or more, and the soils were as uniform as possible. In some cases excessively wet seasons flooded out the plots and destroyed the experiment, but the results of those in which this did not occur are given below, and speak for themselves.

In 1906 experiments were conducted on Oats and Barley. A very marked increase is seen in the case of Oats on Plot No. 3, treated with a mixture of Muriate of potash and Thomas phosphate, which gave an increase of 27.2 bushels per acre. But Thomas phosphate applied alone gave an increase of only 4.4 bushels, clearly indicating that Potash was the ingredient needed in this case. Potash alone increased (



FIG 4.—Corn grown on unfertilized soil, and with Phosphoric acid and Nitrogen, and with a complete fertilizer.

yield 13.5 bushels per acre. From this it will be seen that frequently the application of a mixture gives distinctly larger yields than the application of one ingredient alone.

With Barley the applications did not appear to have so much effect that year. Muriate of potash increased the yield only 11.2 bushels per acre. The further application of 320 lbs. of Superphosphate only gave an additional increase of .2 bushels.

In 1907 Oats and Potatoes were experimented on; the application of Muriate of potash together with lime on Plot No. 2 gave an increase of 8.0 bushels, while on Plot No. 3, to which 400 lbs. of Thomas phosphate was applied in addition to the lime and potash, the yield was only increased 3.6 bushels. This shows that potash was needed, whereas the Phosphoric acid in this particular case gave no result.

The potatoes responded most readily to a compound fertilizer also.

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i.e., Sulphate of potash 200 lbs. and Thomas phosphate 400 lbs., together with 1,400 lbs. of lime, the increase in yield being 106.8 bushels per acre. Sulphate of potash and lime increased the yield 77.4 bushels per acre. Lime alone also increased the yield 53.5 bushels, but in this connection it must be stated that the addition of lime resulted in scabby potatoes. Therefore, if lime has to be applied to correct acidity in certain cases, it should be applied to a previous crop.

In 1908 experiments were conducted with Oats, Corn and Potatoes. Better results were obtained this year than in any preceding one. The unfertilized plot in the case of oats yielded but 4.5 bushels per acre. Lime here gave a very marked increase of 26 bushels per acre. The soil experimented on was of an acid character, badly in need of liming. Lime and Muriate of potash increased the yield 32.5 bushels per acre.



Fig. 5—Experimental plots on P. S. McLaren's farm, Perth, Ontario.

whilst a mixture of lime, Muriate of potash and Thomas phosphate gave an increased yield of 36.5 bushels per acre.

Corn gave the best results of all, under an application of Muriate of potash, the yield being increased by 1,340 pounds of husked corn per acre. Lime had no effect at all, and the application of potash and Superphosphate applied together gave an increased yield of 740 pounds per acre. In this case potash was the element needed more than any other.

Potatoes again responded readily to an application of Sulphate of potash by an increased yield of 25.4 bushels per acre, and by an increase of 76 bushels an acre to an application of Sulphate of potash and Thomas phosphate combined. Lime in this case decreased the yield. It will be seen, therefore, that, generally speaking, the potato crop responds readily to a liberal application of a compound fertilizer. In general it may be preferable to use Superphosphate instead of Basic slag on soils which are rich in lime.

RESULTS OF EXPERIMENTS ON MUCK SOILS IN 1909.

Conducted by R. S. Hamer, District Representative, Department of Agriculture,
Perth, Ontario.

Oats.	Fertilizers per acre.	Weight when hauled in. per acre.
	lbs.	Tons.
1. No fertilizer.....		1.1
2. Muriate of potash.....	120	3.1
Superphosphate.....	360	
Nitrate of soda.....	120	
3. Superphosphate.....	360	2.6
Nitrate of soda.....	120	
4. Superphosphate.....	360	
Muriate of potash.....	120	2.8
5. Muriate of potash.....	120	
6. Superphosphate.....	360	2.2
7. Barnyard manure.....	20 tons	2.3
NOTE.—These plots were not threshed on account of being too badly lodged in some cases to make clean threshing possible.		
	lbs.	Bush.
8. No fertilizer.....		16.4
9. Muriate of potash.....	120	25 0
10. Muriate of potash.....	120	28.23
Basic slag, '08.....	360	
11. Muriate of potash, '0.....	120	28.23
12. Muriate of potash.....	120	25.5
Superphosphate, '09.....	360	
13. Muriate of potash, refert'ized.....	120	29.5
14. Muriate of potash.....	120	37.6
Superphosphate, refertilized.....	360	
Rape.	lbs.	Tons.
1. No fertilizer.....		4.4
2. Muriate of potash.....	120	11.8
Superphosphate.....	360	
Nitrate of soda.....	120	
3. Superphosphate.....	360	9.4
Nitrate of Soda.....	120	
4. Superphosphate.....	360	9.6
Muriate of potash.....	120	
5. Muriate of potash.....	120	5.2
6. Superphosphate.....	360	8.6
7. Barnyard manure.....	20 tons.	11.2
	lbs.	
8. No fertilizer.....		2.8
9. Muriate of potash.....	160	2.4
Superphosphate, '08.....	360	
10. Muriate of potash.....	160	6.0
Superphosphate, refertilized.....	360	
11. Muriate of potash.....	160	9.4
Superphosphate, '09.....	360	
12. Muriate of potash alone, '09.....	160	2 8

RESULTS OF EXPERIMENTS ON MUCK SOILS IN 1909.—*Continued.*

Millet.	Fertilizers. per acre.	Tons per acre.
	lbs.	Tons.
1. No fertilizer.....		2.8
2. Muriate of potash.....	120	
Superphosphate.....	360	7.6
Nitrate of soda.....	120	
3. Superphosphate.....	360	4.0
Nitrate of soda.....	120	
4. Superphosphate.....	360	6.06
Muriate of potash.....	120	
5. Muriate of potash.....	120	3.24
6. Superphosphate.....	360	4.04
7. Barnyard manure.....	20 tons	6.12
8. No fertilizer.....		3.0
9. Muriate of potash.....	120	3.2
Superphosphate, '08.....	360	
10. Muriate of potash.....	120	5.8
Superphosphate, refertilize.....	360	
11. Muriate of potash.....	120	5.24
Superphosphate, '09 (1).....	360	
12. Muriate of potash.....	120	3.6
Superphosphate, '09 (2).....	360	
13. Muriate of potash alone, '0.....	120	3.4
14. Muriate of potash alone, '09.....	120	2.8
Mangels.		
	lbs.	Tons
1. No fertilizer.....		4.9
2. Muriate of potash.....	120	
Superphosphate.....	360	16.4
Nitrate of soda.....	120	
3. Superphosphate.....	360	12.1
Nitrate of soda.....	120	
4. Superphosphate.....	360	15.6
Muriate of potash.....	120	
5. Muriate of potash.....	120	15.3
6. Superphosphate.....	360	13.9
7. Garden Loam.....		17.0
8. No fertilizer.....		2.9
9. Basic slag, '08.....	360	3.3
10. Basic slag, refertilized.....	360	4.8
11. Basic slag, '09.....	360	7.5
12. Basic slag.....	360	4.7
Muriate of potash, '08.....	120	
13. Basic slag.....	360	8.8
Muriate of potash, refertilized.....	120	
14. Basic slag.....	360	10.1
Muriate of potash, '09.....	120	

Co-operative experiments were conducted in 1909 with oats, rape, millet, and mangels, the results of which have been presented in tabular form. It will be noticed that the plan of the experiments in 1909 was as follows: With Oats, Rape, Millet, and Mangels, a series of plots numbered from 1 to 7; further, a second experiment with plots numbered from 8 to 14 with Oats, 8 to 12 with Rape, 8 to 14 with Millet, and 8 to 14 with Mangels. The purpose of this second series of experiments was to compare in the case of oats the results obtained on an unfertilized soil with soil fertilized with potash in 1908, in 1909, and in



FIG. 6.—Oats on Plot No. 1, unfertilized.

both 1903 and 1909; and with soil fertilized with a mixture of Muriate of potash and Superphosphate in 1908, in 1909, and in both 1908 and 1909—all worked out in duplicate. In the case of Rape and Millet, the results obtained on an unfertilized soil are compared with those on a soil fertilized with Muriate of potash and Superphosphate in 1908, in 1909, and in both 1908 and 1909. In the case of Mangels, a comparison of unfertilized soil with soil fertilized with Basic slag in 1908, in 1909, and in both 1908 and 1909; and with soil fertilized with Muriate of potash and Basic slag mixed, in 1908, in 1909, and in both 1908 and 1909.

Let us consider the experiment with Oats first. The results of

tained on the first series of plots, No. 1-7, are omitted, because the grain was not threshed on account of being too badly lodged in some cases to make clean threshing possible with a flail, but the cut here given illustrates clearly and in a most emphatic manner the beneficial results of fertilizers on the oat plots. On the succeeding plots, Nos. 8 to 14, some excellent results were obtained. Early Daubeney Oats were sown at the rate of 2 bushels per acre. The unfertilized plot, No. 8, showed a weak, short straw, about 65 per cent. of the grain lodging flat. The grain was light and poorly filled.



FIG. 7.—Oats on Plot No. 4, fertilized with Potash and Phosphoric acid.

Plot No. 9, fertilized with Muriate of potash alone in 1908, gave a thinner stand and shorter straw than the next plot, No. 10. The heads were not as well filled, the yield, however, being 25 bushels per acre, an increase of 8.6 bushels over the unfertilized.

Plot No. 10, fertilized with both Muriate of potash and Basic slag in 1908, gave a good, tall, heavy stand, with not much tendency to lodge. The heads were well filled and matured, and the grain hard. The yield was 28.23 bushels per acre, thus showing an increase of 3.23 bushels over the application of potash alone.

Plot No. 11, fertilized with Muriate of potash alone, in 1909 gave a better crop than the one fertilized with potash in 1908, but not as

good as the plot refertilized with potash (No. 13). Plot No. 12, fertilized with a mixture of Muriate of potash and Superphosphate in 1909, while giving a slightly lesser yield than the last plot, gave a better crop than the preceding in height and stand, of a fine healthy colour, and with practically no rust. It was evenly matured, and heads were filled with good plump grain.

Plot No. 13, refertilized with Muriate of potash, gave a heavy



FIG. 8.—Specimens of Rape grown on unfertilized and fertilized muck soil.

yield, 29.5 bushels per acre, and a much stronger stand than the potash in 1908. Some lodged grain.

Plot No. 14, refertilized with a mixture of Muriate of potash and Superphosphate, yielded splendid results, giving 37.6 bushels per acre, an increase of 21.2 bushels per acre. There was a fine strong stand, tall and well advanced, not much lodged. The heads were the best filled of any.

Some interesting results were experienced with Millet and Rape. The soil was a muck, averaging from 18 to 24 inches in depth, the last

6 inches being chiefly decayed vegetable matter. The subsoil was white sand.

Owing to the fact that even under the best conditions it is ordinarily impossible to get on this particular area much before June, it was considered advisable to experiment entirely with forage crops whose habit of growth adapted them to late seeding. Accordingly, rape and millet were used.

Both the Rape and Millet on the unfertilized plots gave poor results. The growth was thin and short. The best results were obtained in both Rape and Millet on Plot 2, with the addition of a complete fer-



FIG. 9.—Showing Mangels grown on unfertilized swamp land.

tilizer. The growth was strong and uniform and the colour good, and the yield was more than doubled.

The Superphosphate and Nitrate of soda combined (Plot 3), also did well in both cases, particularly the rape.

Muriate of potash alone with both Rape and Millet gave results lower than those obtained by the mixture. This would seem to indicate the lack of Phosphoric acid in these soils, a point which has been frequently referred to. Both Rape and Millet were a thin, short crop all summer, but distinctly better than the unfertilized plot. The result is borne out in Plots 12, 13, 14.

It will be noticed that Superphosphate alone gave better results

than potash alone, particularly in the case of rape, but poorer results than a mixture of both Superphosphate and Potash.

Attention must be drawn to the good results obtained from an application of myard manure (Plot 7), in both cases, the results being a little better than those obtained from the complete fertilizer (Plot 2).

The results from refertilizing with both Potash and Superphosphate are not so marked in the case of rape and millet as they were in the case of oats.

Lastly, the results with Mangels in 1909. The soil experimented



FIG. 10.—Showing Mangels grown on fertilized muck soil. (Complete mineral fertilizer.)

on was a good quality of muck—cleared from a hardwood swamp. The area has been under crop for several years, and the muck was worked down to within eight or ten inches to the clay subsoil. Owing to lack of complete drainage, it is ordinarily not sowed until late in May or the first week in June. Of late years roots have been grown, but the muck has not been manured for several years. Fair crops have resulted, except in years which were very dry during the early part of the season.

It will be noticed in this experiment that high yields were obtained at the end of each area. These high yields possibly cannot be attributed to the influence of the fertilizer alone. It will be noticed that the highest yield of all is obtained on the end plot, No. 7, to which nothing was

added but garden loam. Whether the ploughing in the spring had any influence at this end we are not prepared to say, but the fact that the clay comes nearer to the surface would undoubtedly make some difference—a favourable difference. The beneficial effect, however, of garden loam applied alone, due to its inoculating property, has already been fully discussed in this Bulletin.

It will be noticed that the unfertilized plots in both series (Nos. 1 and 8), gave very poor results, 4.9 tons and 2.9 tons to the acre. The best results were obtained from the complete fertilizer (Plot No. 2), which yielded 16.4 tons to the acre—an increase of 11.5 tons. Muriate of potash alone, and Basic slag alone, with Mangels, both gave good results, 15.3 and 13.9 tons per acre. This may be explained by the fact that the subsoil in this case was of clay, and therefore would be likely



FIG. 11.—Showing effect of Potash and Phosphoric acid on Turnips grown on muck soil.

to contain a fair amount of both these ingredients. The mixture of both, however, on Plot 4, gave an increased yield of 1.2 tons per acre more.

In the second series, Plot No. 14, a mixture of Basic slag and Muriate of potash gave an increased yield of 7.2 tons per acre over the unfertilized Plot No. 8—a very marked result.

Altogether, the results of 1909 would seem to clearly indicate the benefits to be gained from an application of a complete mineral fertilizer to swamp soils, no matter what the crop may be. Farmyard manure also generally gives as good, if not better results. The benefit to be derived from the addition of Sodium Nitrate to a mixture of Potash and Superphosphate would seem to lie in the fact that in these soils, notwithstanding the fact that they have an abundant supply of nitrogen in combination, as organic matter, it is largely a reserve stock and unavail-

able to the plant, which, therefore, readily responds to an application of nitrogen in a readily soluble form, as in Sodium Nitrate.

IMPROVEMENT AND RECLAMATION.

Before discussing the improvement of these soils, it is as well to classify them briefly. In general, they may be placed in one of four classes.

1. Soils in which the muck deposit is very deep, often extending several feet.
2. Soils in which the muck varies from a few inches to about one foot, and with an underlying clay subsoil.
3. Soils in which the subsoil is of sand, or quicksand.
4. Soils which are underlaid by a deposit of marl.

The question as to whether these soils should be tile drained or not, as to whether they should be devoted to the growing of cultivated crops, or whether it is more desirable to permanently pasture them, will depend to a great extent in which of the above classes the soil falls.

TEMPORARY IMPROVEMENT.

In cases where the heavy expense of complete drainage is not considered desirable, the question is often asked can we cause the temporary improvement of these soils by any means—by methods that are easily applied and that will prove profitable from a commercial standpoint. It has been found that an application of straw has much increased the yield, and if, at the same time, Kainite or a Potash salt be applied to supply available potash, much may be done towards temporary improvement.

PERMANENT IMPROVEMENT.

In order that a permanent improvement may be successfully brought about, the physical reasons why swamp soils are unproductive must first be clearly understood. It is caused principally by bad water conditions, the permanent water level being too near the surface. Before any special method of drainage is decided upon, it will always be both desirable and profitable to make a preliminary drainage survey of the land in question, in order to determine its present water level and the depth below the surface of the real water bearing layer. With these facts in mind, the most economical method of reducing the water level can be determined. A system of drainage which taps the water bearing subsoil underlying the humus soil, and lowers the water level to at least 40 inches, by removing the cause of unproductiveness, insures permanent improvement in many cases. In all ordinary cases the removal can best be accomplished by either tile or open drains, and attention to

drainage should always be the first step in the reclamation of these lands. Frequently when the swamp is under water and being reclaimed for the first time, and there is an abundance of surface water to be run off, open ditches often are the most rapid and effective. Once this is effected, the permanent lowering of the water table can be proceeded with. For corn growing it should be lowered to about 42 inches. With a permanent water table of 30 inches, it is certain very little corn can be raised, while with a permanent level of 42 inches first-class crops have been grown on these soils.

In raw muck lands the water will not readily enter a tile, as the pores become clogged. The water level is maintained by some source of water in the higher adjacent land and reaches the muck through a water bearing sand, gravel, clay or marl subsoil, below the muck. The water moves very readily through this, and if a portion of the tile passes through this layer the water level will be reduced to the level of the tile. If this can be done at a reasonable cost, it is generally the simplest and most satisfactory plan. It is of little use, therefore, to attempt to tile drain large areas in which the muck is several feet deep. Such lands had better be permanently pastured, or the muck dug out, allowed to dry, and then used as an absorbent in stables or applied to the land as a manure. Before drainage it is as well in all cases to make a preliminary drainage survey, which consists chiefly in digging a number of post holes in the muck to ascertain the character of the layers below the surface and, more important still, to learn the depth of the subsoil. These holes should be left open for a few days to allow the water to reach its permanent level.

For fairly deep lands, the holes may be bored with a two inch auger welded to a piece of $\frac{3}{4}$ inch gas pipe, with a T screwed on the top to hold the crosshandle. The auger and the pipe used may conveniently be about seven feet long, if needed.

The distance from the surface to the subsoil often varies several feet in different portions of the field, and from the conclusions drawn from such a preliminary survey it is often possible to reduce the permanent water level, and to, therefore, make the whole field productive, by laying short lines of tile where needed in the water bearing subsoil, instead of putting in long lines of tile in the raw muck, where they will inevitably become clogged and do no good. It has even been found that tile laid about $3\frac{1}{2}$ feet deep in raw muck is quite ineffective, for the reasons stated.

"In cases where the muck is but 18 inches deep or so, a different problem from the above is presented. In this case the surface water from the land about them flows into these low places. This surface water simply needs to be kept out. The ordinary tile layer simply runs the tile through the centre of these spots, and of course fails to reduce the water level below the level of this tile, which is generally too near the surface in these low places, although it may be $2\frac{1}{2}$ to 4 feet deep in the higher portion of the field. The simplest way to keep out the sur-

face water from the surrounding land is to divide the tile line at the edge of the spot and send a line around on each side, uniting the lines again when beyond the spot. This permits the tile to pick up the drainage water from the surrounding land before it gets to the low places. A number of farmers who have tried this simple and inexpensive method have reported it very effective in changing barren, unproductive spots into the most productive portions of the field." The above method has been taken from Mr. Huston's Bulletin on "Unproductive Black Soils."

The drainage is best accomplished at first by means of open ditches at frequent intervals. Muck soils settle greatly when drained, and if tiles are laid in the soft muck they will rise towards the surface, and thus become ineffective. Drainage is most effective when carried out gradually, and the soil should not be allowed to dry out too quickly, since its mechanical condition may thus be injuriously affected, its absorptive power for water in many cases almost completely destroyed, and the decomposition of the organic matter greatly retarded. After the soil has become firm, tiles may be laid, especially if collars are used.

As to whether it is advisable to tile drain will depend on the nature of the subsoil. If it be a stiff hard pan, extremely difficult to work and break up, little will be gained by tile drainage, for the simple reason that all the surface water the muck holds will drain off and no more water will be able to rise from below through the hard pan, and thus the soil dries out and crops die off. On the other hand, if the soil belongs to class one and be very deep, it is advisable to burn off some of the surface soil, being careful not to let the fire run too deep, and then put in a system of drains if the subsoil be one of clay or marl.

A sandy subsoil, provided it is not quicksand, may be profitably drained. After drainage subsoiling should be resorted to, when the underlying stratum is of clay, and thus in all probability rich in potash and most likely in Phosphoric acid. The nitrogen is nearly all in the top soil, and potash largely in the subsoil. The chief problem with these particular soils is to bring these two plant foods together in the top soil sufficient for the needs of the growing crop, especially during its earlier growth before its roots reach the lower stratum. This may be accomplished by deeper ploughing, to a depth of 18 inches or so. When the top soil is too deep for this, or the subsoil is sandy, this method of treatment cannot be followed. Many correspondents have remarked that the more they cultivate their swamp soils the better is the crop produced. Along with this, the statement has usually been made that the subsoil has been clay, and they have attributed, and quite correctly, the beneficial result to be due to the intermixture of clay and muck. Besides enriching the soil chemically, the physical texture is much improved also. Burning has already been briefly referred to. Where there is a great depth of top soil this method may be followed, and the remaining soil improved, because the ash produced brings up the balance between the various essential constituents for plant growth: but the danger is that the fire will run too deep and destroy all the

organic matter and leave the soil poor in nitrogen. At best the method is wasteful and should not be followed except in extreme cases and at times when the fire can be controlled.

If, after complete drainage, these soils fail to produce satisfactorily, the defect may arise from one of three causes. The soil may have dried out too completely, which has already been spoken of and the remark made, that such soils had better not be underdrained at all, but used as permanent pastures. Or, the soil may contain excessive amounts of some substance, such as proto-oxide of iron, which is known to be poisonous to plants, or else the soil is deficient in some available form of plant food. It sometimes happens, though rarely, that unproductiveness is due to poisoning from the proto-oxide of iron occurring in excessive amounts. Its presence can be easily detected by the unusually dark colour of the soil, which also assumes a reddish tinge when fresh portions of it are exposed to the air. Such exposure causes the lower oxide (proto-oxide) to take up oxygen and to be converted into the higher "sesquioxide" form which is entirely harmless to vegetation. Where this difficulty arises with a soil, the remedy is to thoroughly break it up and work the soil from time to time so as to expose fresh portions to the air. Often, frequent deep ploughing and harrowing during a single season will remedy the matter. When this has been done and the land is in good tilth, its failure can usually be attributed to a lack of available plant food. This will need to be supplied by application of the proper fertilizers; then by giving attention to these, the principal points that confront the farmer, it ought to be an easy matter for him to bring most varieties of swamp soils into a profitable state of cultivation.

In certain cases where it has been conclusively shown that little else but golden rod will thrive on these soils, or rather grow at all, there is but one course to follow, namely, reforestation, with tamarac, cedar, etc., or such trees as were formerly present and as are adapted to swamp conditions. In this way large areas that are at present unprofitable may be made to yield profitable returns.

USE OF MUCK AS A FERTILIZER.

In cases where it will not pay to drain and cultivate muck areas, a profitable use may be made of it as a fertilizer applied to sandy soils to increase the humus material in them. It is best to draw the muck during the summer. Pile it in heaps and allow it to drain. If acid in nature, it is as well to mix it with some quick lime and allow the whole to slake. After drying it can either be applied to the land immediately, or, better still, it can be used as an absorbent in stables, for which purpose it is very valuable, many mucks having the power of absorbing more than their own weight of liquid. When muck is mixed with urine it readily undergoes fermentation, which increases its fertilizing value. The brown mucks are much quicker in their action than the black.

SUMMARY.

1. We have seen how far a complete soil analysis can be of service to the farmer in helping him to understand his soil.
2. As a whole, most swamp soils can be made to be some of our most fertile lands, if properly drained and cultivated.
3. That potash and phosphoric acid are usually more or less deficient, and that the soils readily respond to an application of commercial fertilizers.
4. All attempts at the cultivation of peaty soils begin with drainage.
5. Certain crops are particularly well adapted for growing on these soils, while others do not do so well.

CAUSES OF UNPRODUCTIVENESS.

The following suggestions may be of value as briefly summarizing much that has been dealt with in this Bulletin:

1. A deficiency of Potash (K_2O) and of available Phosphoric acid (P_2O_5), both of which frequently need to be applied in the form of commercial fertilizers.
2. An absence of nitrifying germs which act on the inert nitrogen present in the organic matter and convert it into nitrates, a form readily assimilated by plants. The application of farmyard manure or garden loam is needed in this case, together with frequent cultivation.
3. A water-logged condition owing to the permanent water table being too near the surface, and thus checking root development, and preventing aeration of the soil. Lower the water table by efficient drainage.
4. A dry loose condition of the soil which results in lack of moisture through inability to raise water by capillarity. This condition frequently results from too rapid draining and subsequently the complete drying out of deep areas of muck. Gradual draining is desirable.
5. The laying of tile in the muck itself, which results in imperfect action of the drain, owing to the inability of the water to penetrate into the drain through the pores of the tile.
6. Acidity, owing to the presence of an excess of organic acids. This condition is not common with Ontario muck soils. Liming is the remedy.
7. The presence of injurious plant poisons in the soil, as the lower oxides of iron. Frequent cultivation and exposure of the material to the air results in oxidation and removes the evil.
8. An undecomposed condition of the soil and the presence of much woody fibre and thus a general coarseness of the soil particles. Drying out is apt to result. Frequent cultivation and the application of farmyard manure has a beneficial action, hastening decomposition.

9. The lodging of grain and a light and poorly filled ear, due to the excess of nitrogen over mineral constituents. An application of potash and phosphoric acid is beneficial.

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